Rotary self-spinning on/off valve for digital hydraulic applications

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Digital control of hydraulic systems using on/off valves is a potentially more energy efficient alternative to throttling valves. Efficiency is achieved with digital control by operating the control valve exclusively in its two most efficient states: either fully open, where the pressure drop across the valve is small, or fully closed, where there is zero flow through the valve. To achieve high system performance and efficiency, the on/off valve must be fast, have large flow area, and require minimal actuation power.

Our approach to achieving these objectives is a unidirectional self-spinning rotary spool valve designed specifically for pulse-width modulation (PWM). In comparison to conventional linear valves, the continuous rotary motion of our valve reduces the valve actuation power from a cubic dependence on PWM frequency to a square dependence by eliminating inertial forces due to spool or poppet motion reversals during transition. An added feature of our valve is that it scavenges fluid momentum and throttling energy for rotation, which eliminates the need for external actuation. One application of this valve is to couple it with a fixed displacement pump to achieve a virtually variable displacement pump (VVDP) function. A VVDP based on a non-optimized prototype valve operating at 15Hz PWM frequency has experimentally demonstrated 65% efficiency at 50% displacement. A validated model of the system projects that an optimized valve, along with a novel transition loss reducing mechanism, is capable of achieving 84% efficiency at 15Hz and 76% at 75Hz with similar improvements in efficiency across a broad range of displacements. In addition to the VVDP, the rotary on/off valve is being considered for other applications, such as virtually variable displacement pump/motors and linear actuators.